Project Proposal

The Realtime Hurricane Wind Analysis Project as proposed to the HPCC committee in August of 1998.

A Distributed, Real-time, Hurricane Wind Analysis System

An FY99 proposal to the NOAA High Performance Computing and Communications Program

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Theme: Crisis / Disaster monitoring or response
FY 1998: $75 K NOAA, $75K FEMA (through NIBS)
FY 1999: $75 K *
FY 2000: $75 K *
*(This proposal is also being submitted to competitive process at FEMA for matching funds)

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Executive Summary

Timely information on the actual areas impacted by a hurricane's eyewall and strongest winds at the earliest stages following a disaster should assist emergency managers in allocating recovery resources, detecting potential search and rescue areas, and assessing storm damage before visual inspections are possible. We envision an interactive system will allow scientific users to select a storm, focus on a particular time in the history of the storm in a graphical manner, examine and quality control the real-time data collected during the time period of interest, analyze and archive the wind field, and create a variety of graphical analysis products or data sets derived from the wind field. Portions of the system will be automated rather than interactive to facilitate transfer of the technology to the National Hurricane Center as a tool for forecast and warning guidance. A separate application will allow emergency manager users to select from a menu of products derived from the wind field and formatted to facilitate input to GIS/ damage assessment software such as HAZUS from FEMA.

1. Statement of Problem

Response to a hurricane disaster depends on obtaining accurate and timely information on the magnitude and geographical distribution of the damage caused by the disaster. This information will determine which communities were most devastated and require immediate attention; it will also assist decision-making associated with the recovery process. Advances in computing and communications have made it possible to obtain tropical cyclone wind observations in near real-time. However, scientists involved in hurricane forecasting and research have few tools that enable real-time interaction and analysis of these data. Hurricane wind fields are determined subjectively based on the specialist's interpretation of flight-level reconnaissance data, satellite observations, pressure-wind relationships and available surface data. These fields are represented by text portions of the NHC forecast product as radii (from the storm center) of 34 kt, 50 kt, and hurricane force winds in four compass quadrants relative to north. Emergency managers require accurate and fine scale wind field information to input to geographic information systems (GIS) and damage models. Emergency managers have access to only coarse scale information on the wind field through the wind radii information provided in NHC forecasts and advisories, and are considering the use of parametric wind models to provide more detailed wind field coverage. These wind models are no substitute for real data and tend to oversimplify hurricane structure by not adequately accounting for asymmetries in the wind field caused by convection, land-sea friction differences, intensification, and environmental wind shear. Furthermore such models may contradict the operational forecast information which could lead to confusion among emergency managers.

2. NOAA HPCC Program Relevance

This solution conforms with the goal of NOAA's HPCC program to disseminate real-time and historical information to users more completely, in usable forms, and in a timely manner through the Internet. The analysis system will help to fulfill NOAA's strategic plan objective to advance short-term warning and forecast services. This proposal also addresses FEMA's goals to reduce loss of life and property and protect our nation's critical infrastructure from hazards through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response and recovery. It is critical for public safety that storm information exchanged between the agencies be consistent, accurate, timely, state-of-the-art, with some indication of an associated level of uncertainty. The three year time period for the project was chosen to parallel FEMA 's development of a wind module to their HAZUS GIS software. Matching funds for FY 1998 were committed after the PI made a formal presentation of the HPCC proposal to the panel of wind experts chosen to guide the HAZUS wind module effort by FEMA and the National Institute for Building Sciences (NIBS). When completed, HAZUS will be freely distributed to state and local emergency managers. Tropical cyclone analysis system products derived from real-time and archived wind fields will be designed for input to HAZUS. The wind module of HAZUS will allow storm information to be combined with geographic and demographic databases to produce specialized loss assessment maps for recovery management and the formulation of mitigation strategies. These uses of storm information are consistent with the findings of a recent National Science and Technology Council symposium "Real-time Monitoring and Warning for Natural Hazards" (EOS 1998) and a recent National Academy of Sciences (1996) report, "Computing and Communications in the Extreme" which identified challenges confronting crisis managers, including: 1) "need for cooperation among many different actors", 2) "need to rapidly identify, collect, and integrate crucial information about the developing situation", and 3) "capability to make projections and initiate actions in the face of an inevitable degree of uncertainty and incompleteness of information".

3. Proposed Solution

We propose a real-time system for examining, synthesizing and objectively analyzing meteorological observations in hurricanes, using a common framework for wind exposure, measurement height, and averaging time. This system will allow scientists to interact with the observations, perform quality control, and select from a menu of several graphical products depicting meteorological fields for storm diagnosis and forecast guidance. Automation of several of the procedures will also make it possible to perform operational analyses on a regular 3 or 6 hour schedule consistent with NHC's warning and forecast cycle. For prelandfall cases, operational analyses could be combined with forecast error statistics and projected along an envelope of potential storm tracks as a set of products for disaster planning. For hurricane landfall cases, the system would provide a menu of products designed specifically for real-time emergency management damage assessment applications. These fields will be formatted to be readily input to GIS and damage modeling software such as FEMA's HAZUS. All available wind measurements gathered by reconnaissance aircraft, satellite remote sensors, airborne Doppler radar, ships, buoys, coastal and inland automatic weather stations will be automatically downloaded, preprocessed, and stored using a modern object-relational database located on a dedicated server. One or more additional machines will be dedicated as an objective analysis server and an application server. The application server will use distributed objects to communicate actions and events between the clients and the database and analysis servers. All data and analyses will be archived on the database server and JAVA applets and IDL will allow graphical and gridded products to be created dynamically from the analysis archive and delivered to the client "on the fly". Scientific users would interact with the data and archive through a hardware-independent Web browser client or by a JAVA workstation client. Emergency managers would interact with current products based on operational or poststorm analyses through a Web interface. For scenario studies, users could construct products searching the archive by year, storm name, storm category, or geographic area.

a. Object-Oriented Approach

Object-orientation benefits entire projects, not just individual subsystems through code reuse, use of design patterns, rapid-development, more accurate resource estimation and more effective and efficient testing and maintenance. In light of these benefits and because vocabulary, notation and strategies are easily shared throughout an object oriented project, this project and its subprojects will use an OO iterative development method from beginning to end. The project has three basic subsystems: 1) Quality Control, 2) Analysis Automation, and 3) Output Generation (Powell et al. 1997). A graphically-oriented Quality Control (QCClient) subsystem session involves selecting desired observation types to be viewed, and determining a storm-track-based time window for viewing the data. Decisions are made about data validity through visual nearest-neighbor comparison and inspection. Data are then passed through a series of Analysis Automation subsystem components which are stand-alone programs distributed to allow access from different client machines. All steps in the analysis process are archived in a modern off-the shelf database management system. The Output Generation Subsystem creates graphical representations of various wind field based products via calls to off-the shelf data visualization software.

b. Database dependence

The database approach to data archival provides several advantages over traditional file processing approaches. Among these are: 1) self description, a database's ability to not only contain data but to contain a description of itself, 2) insulation between programs and data, 3) data abstraction (users are not required to understand the internal data structures or the methods that manipulate them), 4) support of multiple views of the same data and 5) sharing of data and multi-user transaction processing. Furthermore, a good database system automatically solves many of the problems inherent in most data processing projects such as controlling redundancy, restricting unauthorized access, providing for persistent storage of program objects and data structures, representing complex relationships among data, and enforcing integrity constraints for the data (Elmasri and Navathe, 1994). Object-relational databases combine both philosophies (OO and relational) and tend to represent not only the best qualities of OO databases, but also those of relational databases, namely superior storage algorithms (please refer to http://www.storm.aoml.noaa.gov for further details on the Database Evaluation).

c. Platform independence

The JAVA programming language was chosen because its write once, run anywhere strategy lends itself to development and maintenance of one set of code for a wide variety of computing platforms. With JAVA, the proposed application, or suite of applications, needs to be written only once and run either as a JAVA application when running the workstation version or as a JAVA applet embedded in HTML for the web version. Platform independent code coupled with web deployment will allow users to not only use any machine they want (as long as it supports the JAVA virtual machine), but also to be wherever they want on the Internet.

d. Distributed Objects

For computational load sharing, we are using a distributed OO system over several distinct application, analysis, and data servers. Distributed object (DO) technology will provide an immediate solution in the area of analysis automation. The current objective analysis software, written in FORTRAN 77, will be wrapped in C and transparently invoked by a Java client using Java Native Interface (JNI) or any CORBA client. Object distribution aspects of the project are the subjects of a Masters Thesis in Computer Science at Florida International University.

e. Maintenance, Deployment, and Distribution Issues

The operational version of the analysis system will require limited automated quality control and will run on a schedule consistent with NHC warning and forecast cycle. This part of the system will be coded (in FORTRAN) and maintained by NHC, and may use existing code elements supplied by HRD. This version of the analysis will incorporate flat files for data storage rather than a database. The interactive workstation/web version of the analysis system will be coded and maintained by HRD and evaluated at NHC and AOML. This version may be deployed or made available within NHC to interested scientists either as a web or workstation application. Most landfall products and archival products from past storms would be derived from the interactive version. HRD will maintain a database archive of past storms and make this information dynamically available over the Web. For both automated and interactive versions of the analysis system, NHC, HRD, and FEMA will discuss dissemination and delivery of archived and real-time products including product design and content, uncertainty depiction, information security, and digital format for incorporation to GIS.

4. Milestones and Deliverables

FY 1998 Progress by Milestone (a more detailed progress report is available at www.storm.aoml.noaa.gov)

1. 06-01-98 *Completion of rapid prototype application for dynamically querying the HURDAT hurricane storm database and delivering query results and storm track plots to the web*. We developed a rapid prototype application (http://storm.aoml.noaa.gov/Storms/index.html) that dynamically queries the HURDAT ("Best Track") hurricane storm database and delivers results and storm track plots to the web. (accessible from most JAVA 1.1.x capable platforms with internet access. We have recently announced the public availability of this application on the Tropical Cyclone listserver (tropical-storms@upmoist.atmos.colostate.edu).

2. 06-15-98 *Complete operational build of the 1998 HRD Wind Analysis System.* The operational build of the HRD Wind Analysis System is in place and ready for use during the 1998 Atlantic hurricane season. AOML scientists are using this build to deliver near realtime products to NHC. Development for both the QCClient and Analysis Automation subsystems of the new system is ongoing and progressing steadily. In general, all code is up to date with latest jdk release (1.1.6) and implementation of most basic functionality is complete with the notable exceptions being in the area of database integration. Most of the client application subproject and analysis subproject functionality requirements have been met. Some of these requirements for the QCClient application include: 1) map loading and drawing, 2) plotting of wind

observations and storm track fixes in both synoptic and storm relative coordinates, 3) graphical tools such as zooming, observation flagging (quality control), distance/heading calculation and detailed observation inspection and editing, 4) separate "views" panel for immediate graphical response to any changes to data, and 5) file import and export capabilities for legacy data files and landmarks. Some Analysis subsystem completed requirements include: 1) porting of legacy Fortran code to Solaris and HPUX platforms from VMS Fortran, 2) integration of the Java, C and Fortran code to run analyses on both the Solaris and HPUX platforms and 3) initializing a mock Analysis sequence from the QCClient application. We have also developed a generic set of JAVA packages (groups of compiled classes) to promote code reuse among all Java implementations by our development team. Code reuse is important for testing, minimizing errors, saving space and saving time.

3. 07-01-98 *Complete updates to scripts to download and process observations in real time*. The completion date for this task has been pushed back to September 1st because of setbacks experienced in installing, configuring and integrating the LDM software. Most of the framework is complete for this task, but certain adjustment routines have yet to be integrated. As of August 1st, the following data are available to the system via LDM and our decoders: CMAN stations, buoys, ships and METAR data. We are also receiving Air Force Reconnaissance data through LDM, but have yet to decode those data.

4. 09-01-98 *Complete feasibility testing of distributed object technology. Complete testing of IDL for automatic product generation.* This milestone is on track for September 1st completion. An Objective Analysis run consists of 4 steps equivalent to 4 major FORTRAN programs that run both on HP-UX 10.x and Sun Solaris 2.x platforms. In order to make each of these steps callable from any operating system/architecture on the Internet, they have to be distributed as objects. We accomplish this by wrapping (linking together and calling one program with another) the FORTRAN code in Java, an object oriented programming language. To test the crucial steps, we successfully ran the all the Analysis steps with the client machine located in Taiwan and the analysis server located onsite at AOML (Miami, FL). The analysis ran well and helped show us that a CORBA distribution scheme will indeed serve the project. In early July, the HRD Analysis server at NHC replicated the implementation of the Analysis subsystem on the HPUX platform. We are investigating different methods of delivering dynamically generated IDL products over the web. Both CGI and Java based methods are possible, but software licensing, product delivery speed and the intricacy of the code are still issues to be resolved for each proposed method. The IDL procedures are, however, functional on their own when run from a workstation (rather than through the web).

5. 07-01-98 *Completion of Object-Relational Database evaluation*. We have elected to use an Oracle8 database server with object extensions. Oracle8 was chosen based on advantages in manageability, performance, scalability, transaction management and fault tolerance. We installed Oracle8 Workgroup for WindowsNT (5-users) and obtained database training for our application developers and database administrator on Oracle8. Please refer to our Database Evaluation **(www.storm.aoml.noaa.gov)** for further details.

The project software developer and database specialist presented papers at the 14th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology in Phoenix, AZ in January. The principal investigator lectured at the National Center for Atmospheric Research's (NCAR) Advanced Study Program Summer Colloquium. One day of the *Hurricanes at Landfall* Colloquium focused on Surface Winds and Storm Surge. An alpha version of the Java-based QCClient was used in laboratory exercises on hurricane surface wind fields (**www.asp.ucar.edu/colloquium/1998/agenda.html)**. Developers also attended Sun Microsystems' JavaOne Conference (February, San Francisco) and the International Oracle User Group Conference (May in Orlando).

FY-99 Milestones

To +6 mo: Completion of scripts for automated data transfer from space-, aircraft-, ocean-, and land-based observing systems using Local Data Manager. (Duration 2 mo)

To +4 mo: Prototype database schema design and evaluation versions of the database. (Duration 4 mo)

To +7 mo: Continue development of graphical, interactive, workstation/web version of analysis software (H*WIND). Provide software components to NHC for development of operational automated (non-interactive) version of analysis. (Duration 7 mo)

To +10 mo: Design of forecast and Emergency Management (EM) products from automated version of analysis. (Duration 3 mo)

Summer - 99 Evaluation Workstation/Web (interactive) versions of analysis at NHC, AOML

To +12 mo: Design of emergency management and scientific products. (Duration 4 mo)

FY-99 Deliverables: Automated LDM-based data acquisition system. Prototype database for H*WIND development. Evaluation version of H*WIND for testing during 1999 season. Meeting to design graphical EM wind products. Static Web delivery of graphical wind products for EM use.

FY-2000 Milestones

2-2000 Implementation of database to analysis system

4-2000 Integration of distributed objects, database server, analysis server, and application server to analysis system including security and product validity

6-2000 Web interface to archive of analyses including EM product menu

Summer-2000 Final release of interactive version of analysis system including web interface and web access to storm wind field information

FY-2000 Deliverables: Dynamic Web access to archival and real-time wind products, Hardware independent Web front-end for conducting data examination and analysis, Paper describing system for IEEE journal

5. Budget

The project is currently on budget. Matching funding from the National Institute for Building Science will arrive after AOML and ERL finance work out procedures. A potential long term issue is the number of concurrent database user licenses required for efficient use of the analysis system. We will explore this issue further by testing application performance under the current 5 user license.

Budget: A Distributed, Real-time Hurricane Wind Analysis System				
Category	**Description**	**FY1998**	**FY1999**	**FY2000**
Personnel	CIMAS Research Associate, Student Programmer	144	144	144
Travel/Transportation	for conferences, meetings	6	6	6
Totals	.	150	150	150

HRD/NHC Contributions:

Personnel Labor: Principal investigators (HRD, NHC)

Capitol Costs (HRD/AOML): Developer workstations, software, hardware, training, Internet and intranet access. Research observations gathered by NOAA P-3 and G-IV aircraft in offshore and landfalling storms through the HRD annual field program including the Winds at Landfall experiment. C-MAN station enhancement and ASOS station wind exposure documentation required to correct inland wind observations in hurricanes (supported by HRD funding through the U.S. Weather Research Program).

6. Project-related References

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